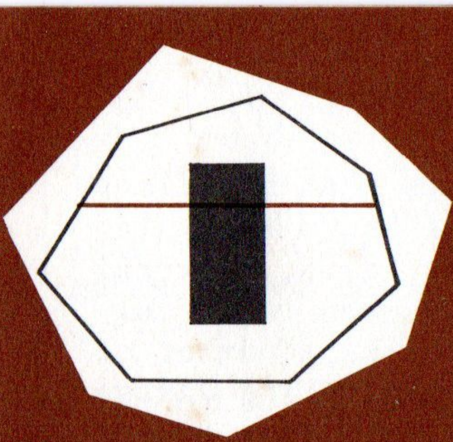
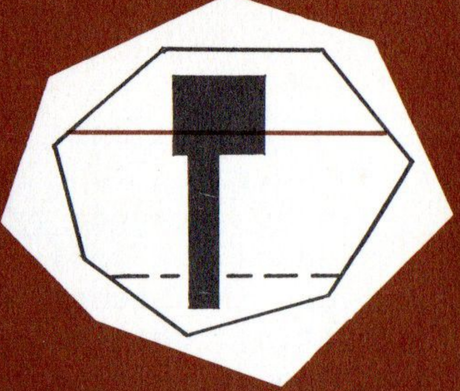
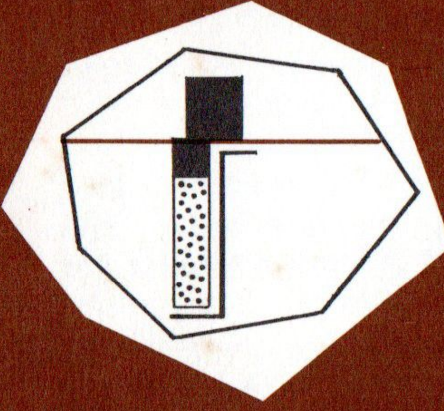
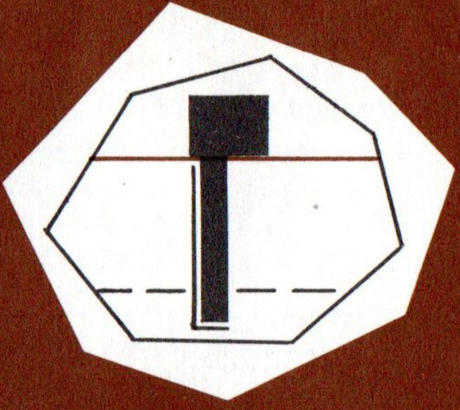
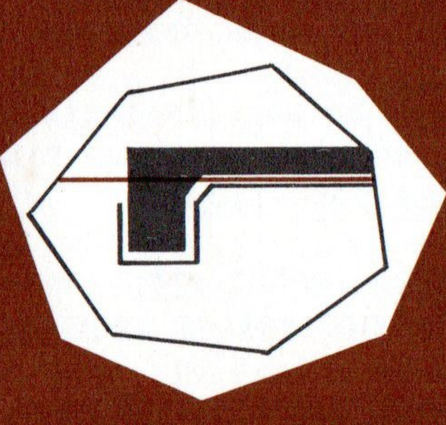


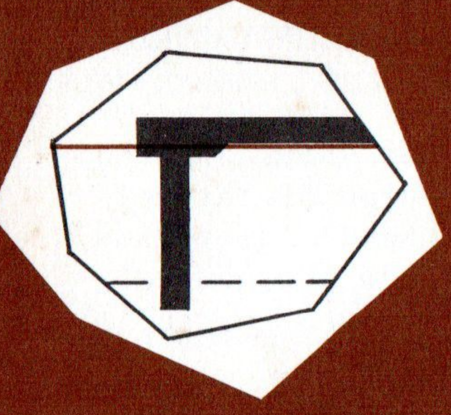


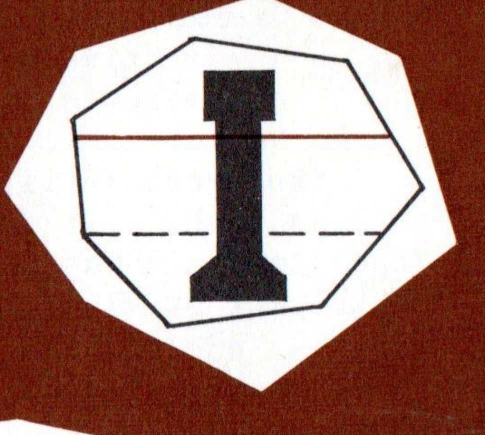
FOOTINGS
for use on South Australian Soils











$1.00

S.A. Department of Mines
and Geological Survey

Introduction

It has been known from the earliest days that buildings in metropolitan Adelaide and other areas of South Australia can be damaged by soil movements. Despite this, careful studies of soils and their behaviour have been made only since the Second World War. From these studies, a number of footing designs were developed, aimed at minimizing damage to house superstructures. These footings have not always overcome the problem, as in many cases they have been inappropriate in either application or construction, but even with proper application and construction, it is possible that some damage would still have occurred. This is because there is a large number of factors which can effect the behaviour of soils and superimposed buildings, and it is still not possible to be certain how any particular combination of soil, footing and superstructure will behave.

There are, however, a number of footing types and practices all in current use, which have proven satisfactory to the extent that they have greatly reduced the incidence and severity of house cracking. The purpose of this brochure is to make a systematic account of these; its detailed objectives are as follows:-

a...... To describe briefly the principles and design features of the various footing types.

b...... To relate the footing types to the soil conditions for which they are considered applicable.

c...... To draw attention to any limitations or special problems associated with each particular footing due to soil or site conditions.

d...... To outline various other practices which have proven effective in preventing or minimizing structural damage to houses.

The brochure is not a design document and should not be used as such. It is designed for use with maps of the Metropolitan Soil Map Series, published by the South Australian Department of Mines. The principles outlined are, however, equally applicable in any other area of South Australia where there is adequate recognition of soil types.

Although knowledge is constantly increasing, confident answers still cannot be given to many problems. Research is being carried out, however, by many bodies, and there is no doubt that future developments will assist in overcoming these problems.

Types of Building Soils

A detailed classification of soils is given in the Metropolitan Soil Map Series and accompanying Explanatory Notes. For the purpose of this brochure however, the soils can be considered as four main types.

Stable Soils

These are soils or foundation materials in which soil movements are not significant in their effect on small buildings. They include compact silts and sands, gravelly soils, weathered rock, and may also include properly compacted fills of suitable type.

Expansive Soils

These have well-defined clay layers containing minerals which react to moisture changes. The clays swell on wetting and shrink on drying, and are termed expansive. They may be slightly, moderately or highly expansive.

The important effect of an increase in soil moisture in expansive clays, is that vertical movements occur within the clay mass and are translated to the soil surface. The movements are accompanied by strong uplift forces which can cause damage to buildings. Differential surface movements may also result from variability of soil profiles or soil moistures over small lateral distances.

Many expansive soil horizons are underlain by more stable soils or weathered rock. Alternatively, expansive clays may occur at depths where the soil moisture is essentially unaffected by seasonal changes or normal surface drainage. At these depths, little or no significant volume changes occur and the soils may be considered "effectively stable". The depths will depend on the soil type and local environment, but are often in excess of ten feet.

Soft or Compressible Soils

These are soils which are unable to carry building loads, without showing significant settlements. Such soils are commonly silts, clays or sands originally deposited under water, and are usually associated with high water tables or restricted surface drainage. They are often underlain at depth by more stable materials of higher strength.

Collapsing Soils

These are soils which show a decrease in volume when their moisture content is increased. They are liable to 'collapse' or sudden settlement under little or no loads, if wetted beyond a certain limit. Soils of this type are mainly sands or limy silts of windblown origin, or deposited under flood conditions. Although very weak in the wet state, in many cases they are cohesive when dry. They also are usually underlain by more stable materials of greater strength, or by clays which may be of expansive nature.

Footing Designs

The type of footing suitable for a particular house is chosen principally from a consideration of the soil conditions at the site. However, details of the footing design also take into account the structural layout of the building, the materials and construction methods to be used, and the soil moisture condition at the time of construction.

The following series of diagrams outline the main design features and limitations of the footing types in current use and relate these to the soil conditions for which they are considered applicable.

The footings include one or more of the following design features.

a...... Sufficient strength and rigidity to resist soil movements, so that damage to house superstructures is avoided.

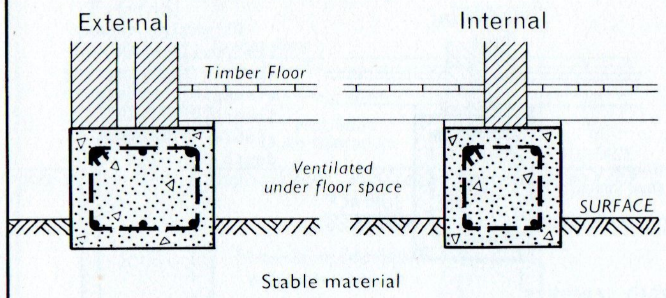
b...... Penetration of unstable soil horizons and support on more stable materials below.

c...... Use of impervious moisture barriers to minimize moisture transfer between soils outside of and beneath building areas.

The footings shown are diagrammatic only. The actual dimensions and reinforcement patterns will depend upon the type and size of the superstructure and the particular soil and site conditions on the building allotment.

The diagrams mainly show footings used in association with timber floors. Isolated and independently poured concrete floors are often equally suitable, but not in situations where high water tables are present or where drainage is a problem.

1. SURFACE STRIP FOOTING



WHERE USED

Stable soils, usually have adequate bearing strength for normal domestic type structures - may include dense silts, sands and gravels, weathered rock, or fill (suitably compacted)

DESIGN FEATURES

Continuous reinforced concrete strip, seated on or near soil surface. Width, depth and reinforcement are adjusted for different foundation conditions.

Poured in sideforms and shallow trenches.

Principally used with timber floors.

LIMITATIONS

Little structural strength and stiffness.

Structural Features

A correctly designed and engineered footing is only one factor contributing to the continued successful performance of a building structure. Careful attention to many other details of design and construction will reduce the chance of subsequent damage. Some particular points are emphasised below:-

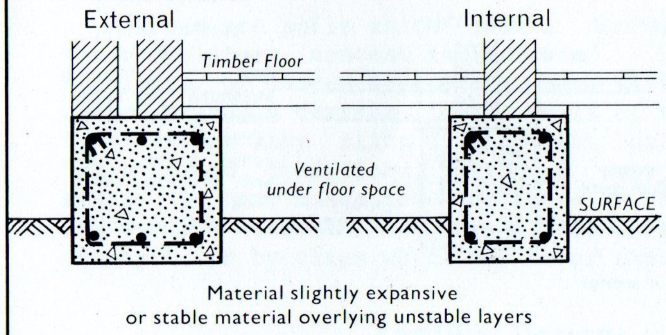
a...... Footing depth and footing reinforcement are usually more important structurally than the amount or strength of the concrete used.

b...... Footings should be arranged in a manner which will give maximum structural rigidity to the whole footing system.

c...... Walls should be in straight lines wherever possible, avoiding projections where their arrangement does not fit into the structural grid.

d...... Construction should permit tolerable movements at openings such as doors and windows, where the structure is normally weakest.

2. SURFACE DEEP STRIP FOOTING


External
Internal
Timber Floor
Ventilated under floor space
SURFACE
Material slightly expansive or stable material overlying unstable layers

WHERE USED

Slightly expansive soils with moderately high bearing strength, or stable layers overlying unstable layers at depth.

DESIGN FEATURES

Continuous reinforced concrete beam of deeper section, seated at or near the soil surface. Width, depth and reinforcement are adjusted for different foundation conditions or wall thicknesses.

Poured in sideforms and shallow trenches.

Principally used with timber floors.

e...... Where roof structures extend beyond the house proper (e.g. for car-ports, verandahs, garages) and are supported by posts or separate walls, it is important that these are on footings which form an integral part of the house footing system.

Additional Precautions and Recommendations

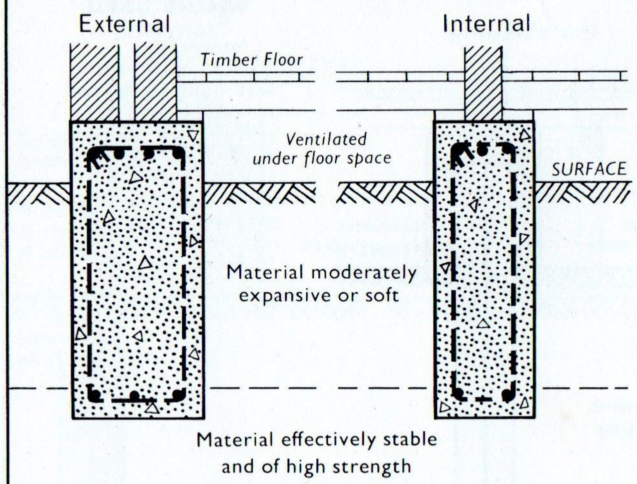
The following practices will also assist in reducing building failures.

a...... Diverting all downhill and surface drainage, sub-soil seepage, roof run-off, septic tank effluent etc., away from building areas in drains of adequate capacity.

b...... Avoiding overwatering of lawns and gardens adjacent to building areas.

c...... Constructing concrete or other impervious pavements around buildings, to reduce the chance of sudden moisture changes in the subsoil below footings and to assist the drainage function.

3. SUBSURFACE DEEP STRIP FOOTING


External
Internal
Timber Floor
Ventilated under floor space
SURFACE
Material moderately expansive or soft
Material effectively stable and of high strength

WHERE USED

Soil moderately expansive or soft in upper horizons.

Underlain by effectively stable soil of moderate to high strength.

DESIGN FEATURES

Continuous reinforced concrete strip of very deep and narrow (controlled by wall thickness) section.

Width, depth and reinforcement are adjusted for different foundation conditions.

Poured mainly in deep trenches with or without shallow sideforms above the surface.

Principally used with timber floors.

LIMITATIONS

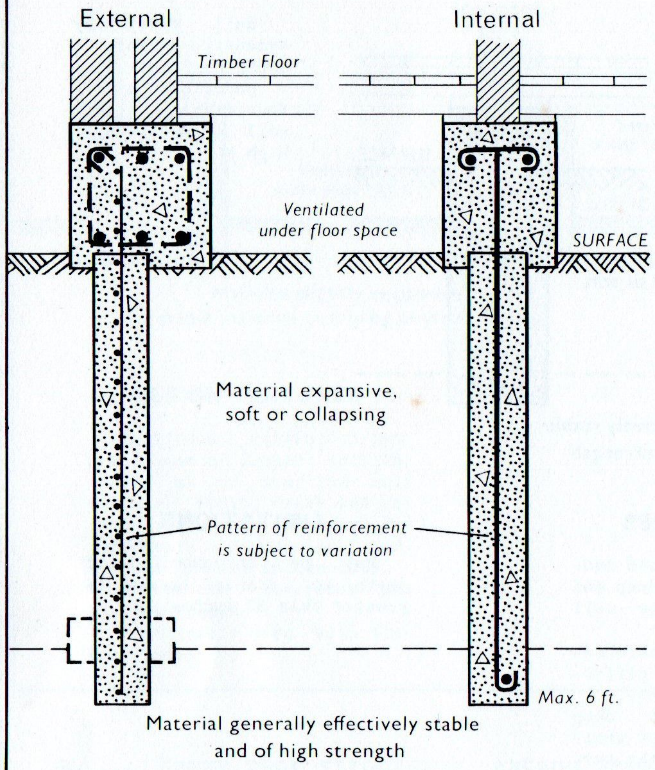
May be uneconomical if depth to stable layers is greater than 30 inches.

Footings on Sloping Sites

Several of the above footing designs are suitable for use on sloping sites, but either the footings will need to be stepped to accommodate the slope, or the site benched to form a level platform.

Many sloping sites are underlain at shallow depth by weathered rock or other essentially stable material. Excavation in these cases may remove troublesome soil horizons completely, leaving the more stable materials exposed over proposed foundation areas. Under these conditions, footing dimensions can be reduced.

4. DEEP TEE BEAM


External
Internal
Timber Floor
Ventilated under floor space
SURFACE
Material expansive, soft or collapsing
Pattern of reinforcement is subject to variation
Max. 6 ft.
Material generally effectively stable and of high strength

WHERE USED

Moderately to highly expansive, soft or collapsing soils, generally underlain at greater depth by effectively stable material of high strengths, but not necessarily so.

DESIGN FEATURES

Continuous, very narrow and very deep beam integral with surface strip footing.

Trenches for the subsoil beams are machine cut, vertical, 6 in. wide and up to 6ft. deep and may be underreamed at base. They are filled with concrete, reinforced by vertical bars or steel mesh.

Surface beams are poured in sideforms and may have different reinforcement patterns.

The deep concrete curtain is designed both as a beam and a barrier to cut off horizontal transfer of moisture in the upper layers.

LIMITATIONS

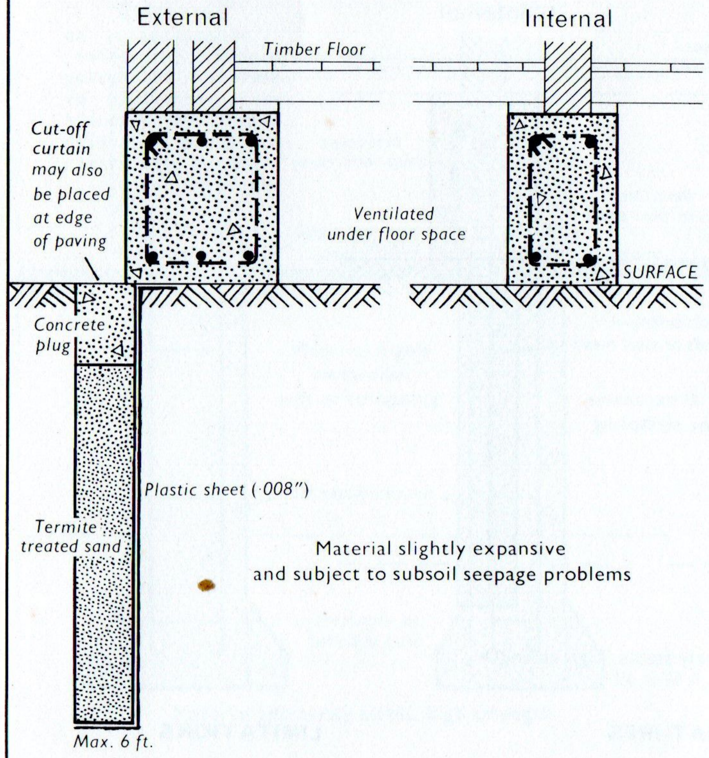
Mainly limited to soils having 'effectively stable' subsoil horizons at less than 6ft. deep.

If dwarf walls are placed on soil surface when soil is very wet, differential movement may occur between such walls and footings when the soil dries out.

Sloping sites generally require benching and levelling.

It may be difficult to cut trenches in ground which is very wet or contains large stone fragments.

5. CUT-OFF CURTAIN (Sand and Plastic)


External
Internal
Timber Floor
Cut-off curtain may also be placed at edge of paving
Ventilated under floor space
SURFACE
Concrete plug
Plastic sheet (·008")
Termite treated sand
Material slightly expansive and subject to subsoil seepage problems
Max. 6 ft.

WHERE USED

Limited application in slightly expansive soils where a moisture barrier is required to prevent horizontal transfer of moisture.

DESIGN FEATURES

Normal continuous deep strip footing to which is added a periphyral moisture cut-off curtain. This is placed at the edge of the outside footing or at the edge of a paving surround.

The curtain consists of a narrow machine-cut trench, which is lined on the inside with a plastic sheet and back-filled with suitably compacted termite-treated sand. The trench is closed at the top by a concrete plug.

The surface footings are normally constructed in side-forms after the cut-off curtain has been installed.

LIMITATIONS

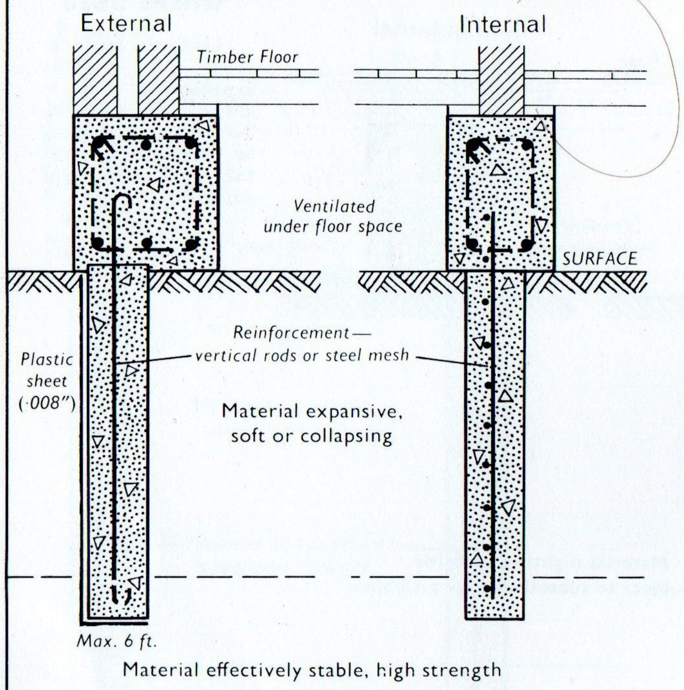
The sand may act as a moisture drain, carrying water from one layer of the soil to another.

It will not prevent moisture loss from beneath floor areas and hence possible differential shrinkage movements of soil below footings.

The system does not add any structural strength to the surface footing.

Trenching may be difficult in gravelly or very soft ground.

6. CUT-OFF CURTAIN (Concrete and Plastic)


External
Internal
Timber Floor
Ventilated under floor space
SURFACE
Reinforcement— vertical rods or steel mesh
Plastic sheet (·008″)
Material expansive, soft or collapsing
Max. 6 ft.
Material effectively stable, high strength

WHERE USED

Moderately to highly expansive, soft or collapsing soil, underlain by effectively stable material of high strength (preferably weathered rock).

DESIGN FEATURES

Surface deep strip footing integral with concrete cut-off curtain (max. 6ft. deep) which is designed to prevent horizontal transfer of moisture. A plastic sheet is usually placed against the external face of perimeter curtain.

Curtains are load bearing and for expansive soils are reinforced by vertical rods or wire mesh. In some cases, reinforcement may be omitted.

LIMITATIONS

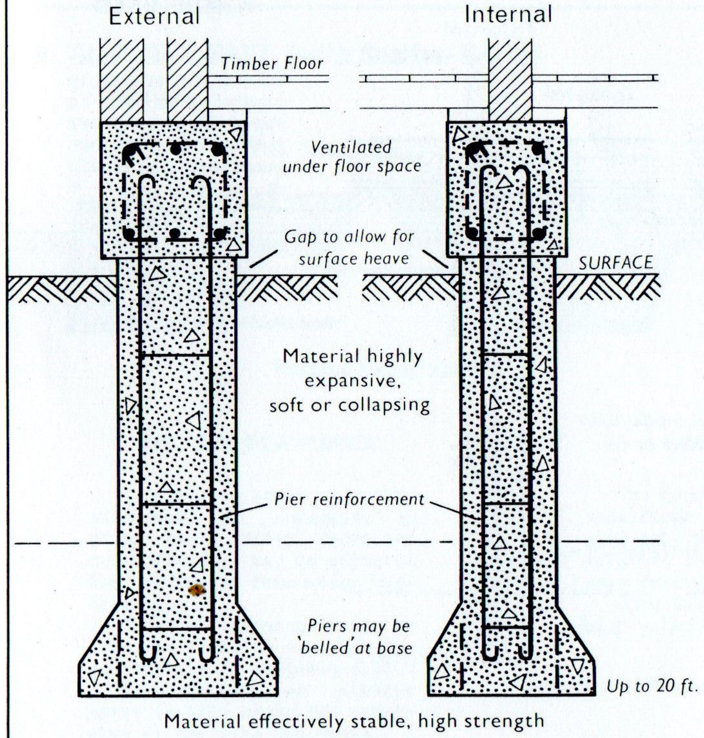
If dwarf walls are used to support timber floors, they may experience some movement relative to the footings.

Trenching may be difficult in gravelly or very soft ground.

Excavations may introduce drainage or seepage problems in unsupported batters. It will then be necessary to divert drainage water, subsoil seepage etc. away from the building area. Excavated faces may also need to be held by retaining walls.

Levelling of sloping sites may entail the use of fill to provide all or part of a building platform.

7. PIER AND BEAM


External
Internal
Timber Floor
Ventilated under floor space
Gap to allow for surface heave
SURFACE
Material highly expansive, soft or collapsing
Pier reinforcement
Piers may be belled at base
Up to 20 ft.
Material effectively stable, high strength

WHERE USED

Highly expansive soils which may extend to considerable depth or for soft or collapsing soils if underlain by effectively stable material of high strength.

DESIGN FEATURES

Piers are designed to carry all superstructure loads to stable strata. They may be "belled" at base to increase bearing area and reinforced to resist tensile stresses imposed by swelling soil materials. Piers for internal walls may be of lesser diameter than for external walls.

Beams are supported on the piers and in the case of expansive soils are kept clear of the ground surface by the maximum amount of vertical heave anticipated.

Beams are poured in side forms on a thin sand bed, which is later removed.

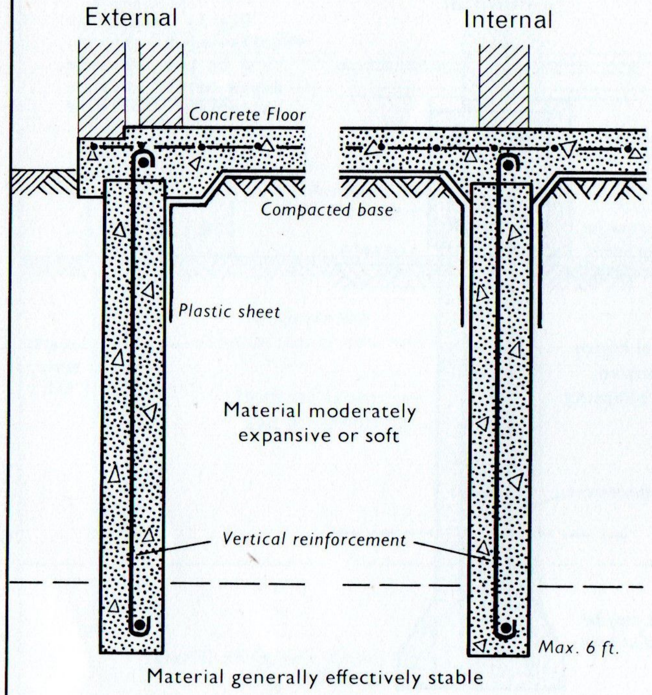
LIMITATIONS

Pier concrete must be sound and fill pier holes completely otherwise water will penetrate to pier base. There may be some difficulty constructing pier shafts in very gravelly or soft ground but liners can be used.

If dwarf walls are used to support timber floors, they may experience some movement relative to footings.

Plumbing to house, particularly sewers, needs flexible joints.

8. GRILLAGE RAFT



WHERE USED

Soils which are moderately or highly expansive or soft in upper layers and are generally, but not necessarily, stable at depth.

DESIGN FEATURES

A concrete raft floor integral with very deep narrow beams formed in machine-cut trenches.

The deep beams form a structural grid and give both edge stability and structural rigidity. They also resist the horizontal transfer of moisture to a significant depth. The concrete floor is underlain by plastic sheeting. This prevents loss of moisture from underfloor soils thus tending to stabilize soil moisture below building areas and reduce relative soil movements.

LIMITATIONS

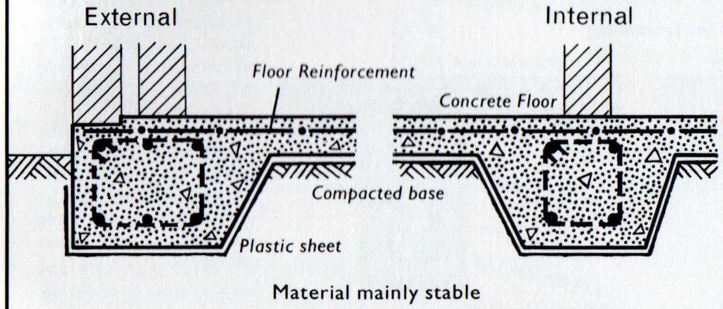
Unsuitable in areas where high water tables are present.

Trenching may prove difficult to construct in very gravelly or soft wet soil.

If floors are placed on dry soil, some heave may result when the ground eventually 'wets up' from below. To overcome this, water can be added to the soil under controlled conditions before the floor is poured.

Some of the points discussed for sloping sites are illustrated in Fig. 11.

9. CONCRETE RAFT (with Shallow Beam)



WHERE USED

Soil effectively stable but bearing strength may be less than for other footing types.

DESIGN FEATURES

Reinforced concrete slab, stiffened on underside by strip beam. Width, depth and reinforcement may be adjusted for different foundation conditions.

Material forming base to concrete floor is usually compacted soil or suitable fill.

A moisture proof plastic sheet is laid under the entire area of the slab and beams.

LIMITATIONS

The concrete slab prevents underfloor evaporation, but will not necessarily prevent moisture changes in soil below edge footings.

Unsuitable in areas where high water tables are present.

Pavements

Unstable soils are likely to cause movement or damage to paved surfaces. Before constructing pavements of any type, the house owner should ascertain its suitability for the particular soil conditions.

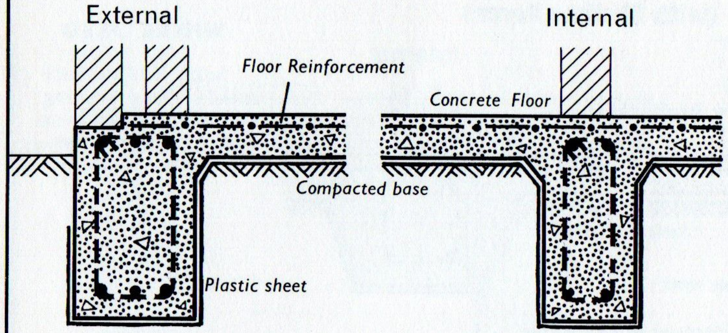
Statutory Requirements

It is necessary to carry out all construction in accordance with the Building Act (1923-1965).

If a lending institution is involved it will require compliance with its own standards.

Some construction details may be subject to the By-laws of local Councils.

10. CONCRETE RAFT (with Deep Beam)



Material may be slightly expansive,
but of moderate to high strength at foundation depth

WHERE USED

Soil slightly expansive in top horizons, underlain by effectively stable material at foundation depth.

May also be used where top horizons have low strength, provided they can be compacted before footings are constructed.

DESIGN FEATURES

Deep subsurface strip footing integral with reinforced concrete slab. (Width, depth and reinforcement of edge footings adjusted to foundation conditions at each site).

Material forming base to concrete floor is usually compacted soil or fill.

A moisture proof plastic sheet is laid under the entire area of slab and beams.

LIMITATIONS

Unsuitable in areas where high water tables are present.

If soils are dry at time of slab construction they may later take up moisture and possible heave may result. To overcome this water can be added to the soil under controlled conditions before the floor is poured.

Professional Advice

It is always advisable (and usually required by Lending Institutions) to seek advice on soils and footings before commencing any building project. Names of persons qualified to provide this advice may be obtained from:-

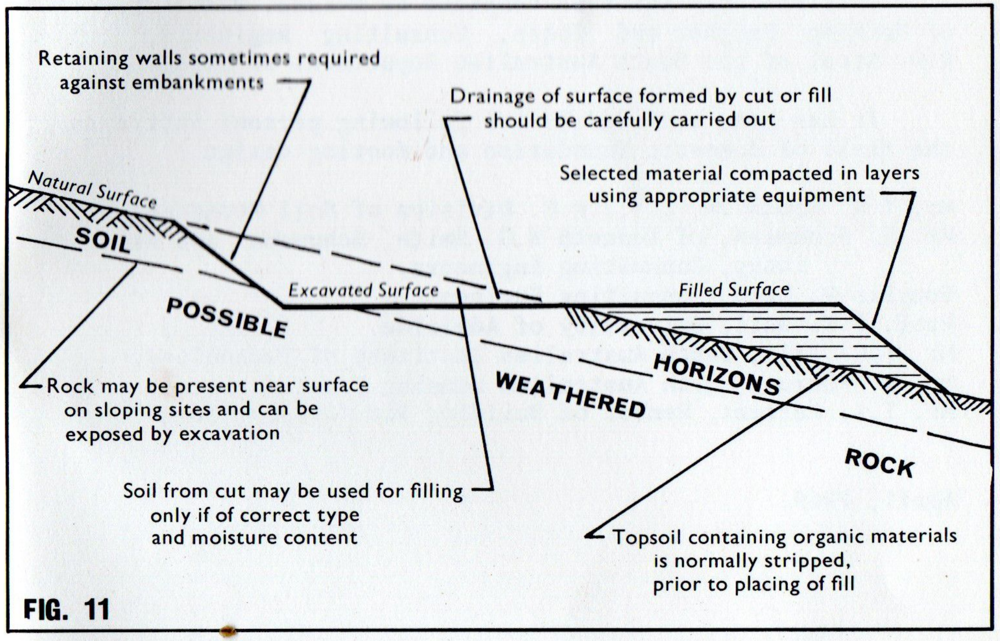
The Department of Mines, 169 Rundle Street, Adelaide.

The Institution of Engineers, 11 Bagot Street, North Adelaide.

The Adelaide Building Centre, 47 South Terrace, Adelaide.

Lending Institutions

Local Councils



Retaining walls sometimes required against embankments

Drainage of surface formed by cut or fill should be carefully carried out

Selected material compacted in layers using appropriate equipment

Rock may be present near surface on sloping sites and can be exposed by excavation

Soil from cut may be used for filling only if of correct type and moisture content

Topsoil containing organic materials is normally stripped, prior to placing of fill

FIG. 11

This brochure has been compiled by Messrs. P.J. Fargher of Hosking, Fargher and Oborn, Consulting Engineers, and R.D. Steel of the South Australian Department of Mines.

It has been reviewed by the following persons active in the field of domestic foundation and footing design:

Mr. T.A. Woodburn, C.S.I.R.O. Division of Soil Mechanics.
Mr. E. Schumann, of Kenneth W.G. Smith, Schumann and Associates, Consulting Engineers.
Douglas R. Reid, Consulting Engineer.
Prof. F.B. Bull, University of Adelaide.
Mr. K.C. Pile, South Australian Institute of Technology.
Mr. M. Pocius, South Australian Housing Trust.
Mr. T.A. Farrent, Member of Building Act Advisory Committee.

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Address

Department of Mines, 169 Rundle Street, Adelaide, South Australia 5000

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